A BIOLOGICAL STUDY OF THE LAKES OF THE PIKE'S PEAK REGION—PRELIMINARY REPORT

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WITH THREE PLATES

The Pike's Peak region lies in the east central part of Colorado, about 38° 30″ north latitude and 105° west longitude. Here, within a few miles of each other, are two groups of lakes representing quite different types, the alpine and those of the plains (pl. V). The alpine lakes lie far up on the mountains at altitudes varying from 3110 m. to 3625 m., with typical alpine surroundings. The plains lakes lie on the western edge of the Great Plains at altitudes varying from 1800 to 2000 m., and with conditions which are in no wise alpine. They are lowland lakes.

THE ALPINE LAKES

In the region south and east of Pike's Peak there were a number of natural bodies of water which were known as Lake Moraine, Dead Lake, and the Seven Lakes (pls. V and VI). In addition to these there have been constructed from time to time a number of reservoirs. Lake Moraine has been changed to a reservoir and within the last two years Seven Lakes have been much altered by the construction of dams which have converted three of these lakes into one large reservoir (pl. VII), and have destroyed two others. Of these lakes the writer chose six as representative and in addition a small pond near the top of Bald Mountain. These seven lakes, from which collections were made, were Moraine, Dead, Mirror, Ribbon, Isoetes, Michigan, and Bald Mountain. Several collections were also made from Marsh Lake.

These lakes, with the exception of Bald Mountain, have been described by Ward (1904). In addition to those studied by the writer, Ward also included Lake of the Rocks and Lake Ramona—mere ponds—which were destroyed in the construction of Reservoir No. 4.

The alpine lakes studied, together with the elevation, the area, and the depth of each, are given in the list below:

Lake	Elevation	Area	Depth
Moraine	3110 m.	39.65 ha.	8.5 m.
Isoetes	3285 m.	1.06 ha.	2 m.
Michigan	3285 m.	1.1 ha.	1. m.
Marsh	3287 m.	0.5 ha.	0.5 m.
Ribbon	3290 m.	3 ha.	4.5 m.
Mirror	3292 m.	33 ha.	8 m.
Dead	3350 m.	1 ha.	2 m.
Bald Mountain	3625 m.	3 ha. (of small pools)	0.5 m.
(Reservoir No. 5	3292 m.	50 ha.	18 m.)
(Reservoir No. 4	3290 m.	50 ha.	15 m.)

Reservoir No. 5 was built on the site of Marsh, Ribbon, and Mirror lakes. Although the dam was constructed in 1905 the water did not rise high enough to include Mirror and Ribbon lakes until the spring of 1906. Collections were made from the original lakes up to that time. The collections made during 1906 were, however, from the reservoir and on the sites of the original lakes. During 1905 collections were taken from reservoir No. 4, but during 1906 this reservoir was dry.

As pointed out by Ward (1904: 138) these lakes are higher than any from which plankton studies have been reported, either in this country or in Europe. The difference in altitude between these lakes and the European lakes studied by Zschokke (1900: 1) is very marked. The highest lake included in his lists was Fuorcla de Flex, 3050 m., which is 60 m. lower than any of the alpine lakes studied by the writer. On the other hand, it is 242 m. below Mirror Lake and 576 m. below Bald Mountain Lake. Zschokke (1900: 2, 40) includes all lakes above 1500 m. as alpine, but such a limit is not to be applied in this portion of North America, as already pointed out by Ward (1904: 133). Latitude as well as general climatic condition should be taken into account. Perhaps a far better method of comparing alpine lakes would be to take the distance above or below timber line. This line, although not absolutely uniform, is to a great degree an invariable altitude in each section of the country. In a way, it is a measure of the alpine condition and a lake lying above timber line, area and depth being equal, will show more extreme mountain conditions than one lying below, even though the altitude is less.

Timber line on Pike's Peak is at an elevation of 3573 m. (11,720 ft., Hayden Survey). In the following table the distances above or below timber line are given:

Lake Moraine................	363 m. below timber line.
Isoetes Lake..................	288 m. below timber line.
Michigan Lake...............	288 m. below timber line.
Marsh Lake..................	290 m. below timber line.
Ribbon Lake.................	293 m. below timber line.
Mirror Lake..................	295 m. below timber line.
Dead Lake...................	275 m. below timber line.
Bald Mountain Lake..........	52 m. above timber line.

Many of the lakes of the Alps lie above timber line and while they do not have as high an elevation the alpine conditions are much more extreme than are those in the region under consideration. A glance at this table will show only one lake, Bald Mountain, above timber line and this lake is really only a series of pools.

Bald Mountain Lake is surrounded by an alpine meadow, a thick turf of mat plants and grasses. In addition to this there are gravel slides which, however, do not reach to the water's edge. There are also many large rock fragments lying in and about the ponds. Mirror and Ribbon lakes were largely surrounded by mountain meadow, but a coniferous forest covers Bald Mountain, which rises rather abruptly above the site of Mirror Lake, and this forest formerly extended along the edge of Ribbon Lake. This portion of the forest has since been cut away and the site of Ribbon Lake is now several hundred meters removed from forest growth.

Isoetes Lake has a forest lying on the south side, Marsh Lake was surrounded by swamps, and Michigan Lake is bordered by swamp, thicket, and forest. Dead Lake lies near a dense coniferous forest, but is also bounded by thicket and meadow (Shantz, 1905: 256). Lake Moraine is bounded by thicket, coniferous and aspen forest, and, on the lower side, by a dam. Bald Mountain and Michigan lakes receive practically full sunlight, as did also Marsh Lake. The others were shaded during part of the morning. This was true of Mirror Lake especially.

Shore and Bottom.—The shore of Mirror Lake was of clean gravel, with the exception of a small portion, where a certain amount of plant remains and ooze was carried in from a swampy area. There was no growth of higher plants and no algae were visible in the littoral region. The bottom of the lake was of blue

clay. Ribbon Lake had practically the same condition of shore and bottom as had Mirror Lake. In Isoetes Lake the shore line is partly swampy and partly gravel, while the bottom is covered to some depth with ooze. Within the last two years the water has been filled with silt. This is due to the fact that Marsh Lake had been drained into this lake and also that a reservoir was being constructed just above it. The level has been lowered so as to expose the whole shelf of the lake. Here we find a dense growth of *Sparganium*, forming a zone around the lake and also an inner, much interrupted, zone of *Batrachium*.

Michigan Lake is completely overgrown with *Sparganium* and contains, in addition, a great deal of moss. The bottom is covered to some extent with organic remains, but the net also brings up clay and gravel. Dead Lake has a rather clean gravel and clay bottom, but in certain places there is a considerable amount of organic ooze. Lake Moraine has a clean gravel bottom, but at the upper end the growth of *Carex* has produced great masses of peat which float out into the lake and which are removed from time to time by workmen.

Water Supply.—The water supply of Dead Lake and Michigan Lake is entirely from springs, as was also that of Mirror Lake, with the addition of the run-off from a very small area. Since the surrounding area is well covered with vegetation, this surface water does not bring an appreciable amount of silt to these lakes. Ribbon Lake was supplied directly from Mirror Lake, while Marsh and Isoetes lakes received the overflow of Ribbon Lake. Lake Moraine is fed by Ruxton and Beaver creeks, the water of the latter being ditched and piped into the former. Bald Mountain Lake is fed entirely by springs. All of these lakes have an outflow with the single exception of Dead Lake which is a closed lake.

Temperature.—The following table gives the temperature readings in Centigrade units recorded during 1904:

Lake	May 20	June 4	June 17	July 12	July 29	Aug. 12	Aug. 26	Sept. 17	Oct. 3
Bald Mountain			1°	10.8°		12.2°	9°	6.8°	
Dead	1.1°–4.7°	6.2°	12.2	13.6	13.6°	15.6	13.8	12	9°
Mirror	1.1 –4.8	6	8	16	13.6	13.6	13	11.8	10.5
Ribbon	1.1 –3.2	5.5	9	16.2	14.8	13.6	11	11	12
Michigan	1.2 –5.8	6.5	8.4	22	14.6	16	15	15.2	15.2
Isoetes	9.8	5	9	17.6	16.2	15	13.8	14	15
Moraine	1.1 –6	8	10.4	13			13	13.3	

On May 20 all of the lakes with the exception of Isoetes Lake

were partly covered with ice. The highest temperatures obtainable at this time were taken near the edge in the most open part of the lakes.

The high temperature recorded for Isoetes Lake on May 20, 1904, was due to the drainage of Marsh Lake into this lake at that time. On June 4 a heavy snow storm lowered the temperature of all the lakes, and there was still some ice remaining at portions of the shore. On June 17 Bald Mountain Lake was covered with a thin ice sheet.

In respect to temperature Zschokke (1900: 20) divides alpine lakes into three categories: First, lakes of considerable size and depth; second, ponds or small, shallow lakes; and third, glacial lakes—lakes fed directly from ice and snow. Although much smaller than the lakes considered by Zschokke the following may be placed in the first category: Mirror Lake (4.8°–13.6°) Moraine Lake (6°–13.3°), and Ribbon Lake (3.2°–14.8°). Dead Lake (4.7°–15.6°), although very small, does not properly belong in either of the other classes and may be included here. All of the other lakes belong to the second category: Isoetes (5°–17.6°), Bald Mountain (1°–12.2°), and Marsh lakes.

The temperature of these ponds is surprisingly low when we consider that there are here many conditions favorable for a higher temperature of the water. Doubtless one reason for the low temperature of these ponds is to be found in the low relative humidity of the air, the rarity of the air, and other climatic conditions which bring about very rapid evaporation and the resulting cooling of the water surface. The air temperature is, however, never very high. Air temperatures taken at the time the water temperature was read range from 0.2° at Michigan Lake, June 4, 3.30 p. m., to 19.4° at Michigan Lake, July 12, 12.30 p. m. With the exception of the last reading the highest temperature recorded was 16°. Another reason for the low temperature of these ponds is to be found in the low temperature of the spring water which supplies them. A very large spring which empties directly into Michigan Lake was found to have a temperature below 6° even in the warmest part of the year.

Temperature readings taken during 1905 and 1906 are about the same as those given for 1904 for corresponding periods of the year.

In none of these lakes was a thermocline found. The bottom

temperature differed very little from that of the surface. The following readings were made July 29, 1904:

Lake	Surf.	1 m.	2 m.	3 m.	4 m.	5 m.	8 m.
Mirror	13.6°	13.6°	13.6°	13.6°	13.6°	13.5°	13.4°
Ribbon	14.8	14.6	14.5	13.8	13.8		
Dead	13.6	13.4					

Readings made on September 17 did not show any relative change in temperature.

For convenience we may divide these lakes into a number of types—closed lakes, open lakes, ponds and reservoirs. Dead Lake, the only closed lake studied, has been described in some detail by Ward (1904: 131–135, pls. XXIV, XXV, XXIX) and Shantz (1905: 256). Of the open lakes there were two—Mirror Lake (Ward, 1904: 132–135, pls. XXIV, XXV, XXVI, XXVII, XXVIII) and Ribbon Lake (Ward, 1904: 131–135, pls. XXIV, XXV, XXVI, XXVII). Mirror Lake was the larger and had no inlet but was connected with Ribbon Lake through its outlet, and Ribbon Lake in turn, through Marsh Lake and Isoetes Lake, with Beaver Creek and thence ultimately with the Arkansas River. Lake Moraine is a reservoir but does not differ essentially from the open lakes just discussed except that there is no overflow, the water issuing from a pipe at the bottom of the lake. This allows the bottom water to escape rather than the surface and would not remove from the lake the true plankton. The remaining lakes, Michigan, Isoetes, and Bald Mountain, and formerly Marsh as well, may well be called ponds. They are small, shallow, partly filled with plant growth and organic ooze, and reach a relatively high temperature.

If we compare these lakes with the general description of a typical alpine lake as given by Zschokke (1900: 40), many points will be found to agree. The water basins lie above 1500 m. and are small and of varying depth. The bottom and shore show manifold local differences as do also the outward conditions. Of the flora, mosses and algae are abundant in the smaller pools. The littoral flora is almost entirely wanting in the larger lakes. The inflow is of water poor in nourishment (varying from 0.6° to 10° except in the case of the lakes which are supplied by streams). The outflow is underground in the case of Dead Lake and also Lake Moraine (an artificial condition in the latter case). The surface is practically undisturbed. The water temperatures are low even in the

middle of the summer, surface temperatures being but little higher than the deeper strata of the lakes of the lowland. The summer maximum and the winter minimum lie close together. The period of ice cover is of long duration. The chemical composition of the water is variable.

A comparatively few points do not agree, but this is to be expected, since the description is of a typical alpine lake and is not intended to include all the conditions which might be found in mountain lakes. The chief points of difference are these: There is no immediate danger of the extermination of these lakes by drought, rock slides, or avalanches. The Characaceae do not occur and, in the greater number, mosses and algae are not present in sufficient numbers to be noticeable. Under natural conditions the level is fairly constant for all lakes under discussion. In only one case is the outflow subterranean.

To a certain extent glacial conditions are present in these lakes. The period during which the lakes are covered by ice sheets has not been definitely determined. It is of comparatively long duration. On May 20, 1904, Mirror and Ribbon lakes were still covered with the ice sheet, except at the very edges, while Moraine and Michigan were partly covered. At Dead Lake the wind had broken up the ice sheet in the early part of the day. Even on June 4 a considerable amount of ice still remained on the protected shores of the lakes. No attempt was made to collect from Bald Mountain before June 17, at which date there still remained a portion of the old ice sheet and the lake had been frozen over anew on the previous night.

The Plains Lakes

These lakes are without exception artificial and have been built largely for purposes of irrigation, with the exception of three, which are used for the storage of drinking water.

Without exception these lakes lie in the open where they receive full sunlight and are not protected in any degree from the wind. The bottoms were originally very uniform. As a rule they were built in gravel areas, but clay or cement has been used to prevent leakage.

Those which were taken as types are given in the following table:

Reservoir	Elevation	Area	Depth (original)
Mesa No. 1 (Palmer's)	2000 m.	1.06 ha.	7.92 m.
Mesa No. 2 (Palmer's)	2000 m.	2.04 ha.	7.62 m.
Mesa No. 3 (Palmer's)	2000 m.	4.04 ha.	9.14 m.
Prospect (Lake)	1830 m.	29.94 ha.	9.14 m.
Portland	1820 m.	2.5* ha.	3.5* m.
Boulder	1829 m.	1.4 ha.	1.8 m.
Colorado Springs No. 2	1890 m.	1.61 ha.	5.48 m.
Colorado Springs No. 1	1886 m.	0.1 ha.	3.64 m.
Colorado Springs (on Mesa)	1900 m.	1.82* ha.	6.1* m.
Becker's	1950 m.	1.0* ha.	2.43* m.
Broadmoor	1950 m.	4.4* ha.	2.43* m.
Jenk's (pond)	1800 m.	1.0* ha.	1.0* m.

*Approximate.

The altitudes given are also only approximate. They are computed from the U. S. topographical map.

Besides those given in the table above, collections were made from two small reservoirs in Stratton Park, one at Pike View, and a number of other small nameless reservoirs. The depths given are the original depths and in the case of the older reservoirs, this figure probably exceeds the present depth. In Prospect Lake, which originally had a depth of 9.14 m., the writer was unable to find a depth greater than 5.5 m. It is probable that measurements of the other reservoirs would have also shown that there had been some filling in since the first construction.

The following table gives the age, in 1904, counting from the year first filled, as well as the source of the water supply:

Reservoir	Age in Years	Source of Water Supply
Colorado Springs No. 1	28	Ruxton, Beaver, and Bear creeks, through city water system.
Colorado Springs No. 2	16	As above.
Colorado Spgs. (on Mesa)	*	Ruxton and Beaver creeks, through city water system.
Prospect	13	As above.
Mesa No. 1	5	Camp Creek, through Glen Eyrie water system.
Mesa No. 2	5	As above.
Mesa No. 3	1	As above.
Broadmoor	17	Cheyenne Creek.
Portland	4	Bear Creek, through a ditch.
Becker's	16	Sutherland Creek.
Boulder	26	Fountain Creek, through El Paso ditch.
Jenk's	very old	Small, unnamed stream.

*First filled in 1904.

The following table gives the temperatures recorded during 1904:

Date		Mesa No. 1	Mesa No. 3	Prospect	Boulder	Portland	Col. Spgs. No. 1	Col. Spgs. No. 2
May	19	15.2°	12.8°					
	23						11.0°	11.0°
	27			13.6°	11.6°			
June	8	15.0°	14.8°				12.6°	11.0°
	15					15.5°		
	22	18.2°	18.2°		23.2°		15.0°	14.8°
	24			18.4°				
July	14			21.0°	21.8°	20.8°		
	21	20.2°	19.0°					
Aug.	6			21.0°	21.6°			
	19					21.0°		
	20	20.6°	21.4°					
Sept.	15	19.2°	18.4°					
	16				17.4°			
Oct.	2			14.6°	12.2°	17.2°	13.6°	15.0°
	4	16.2°	15.0°					

Readings taken during 1905 and 1906 do not present any new variations. Some of the smaller ponds not given in the table above show temperatures as high as 25°.

For convenience these reservoirs may be divided into three types: (1) Those into which the mountain water is piped and which are used for the temporary storage of drinking water; (2) those into which the mountain water is piped, which are used for purposes of irrigation, etc., and in which the water remains for a considerable length of time without change; and (3) those supplied by pipes or ditches from the streams as they leave the mountains and which also receive a great amount of surface water during heavy rains.

In reservoirs of the first type the water is only temporarily stored, there being a constant inflow and outflow. As a consequence, the temperature does not rise above 15°. The water is clean and pure. The bottom is of clean gravel or clay, the banks either of gravel or of granite riprap. There is no plant growth at the shore or bottom. Reservoirs belonging to this class are Colorado Springs No. 1 and No. 2. The Colorado Springs (Mesa) reservoir will doubtless belong to this type, but during 1905 and 1906 the new bed made the water unfit for use and as a consequence it was allowed to remain until it reached a high temperature. Under this condition it would belong to the second type.

In reservoirs of the second type the water supply is the same as

in that of the first. The difference is due to the greater length of time which the water remains in these reservoirs. As far as the writer has been able to ascertain, very little water has been taken out for any purpose and consequently the water has risen to a temperature of 21.4°. In this type there were also found differences of shore and bottom, due to the increase in plant growth resulting from the more favorable temperature. In the older reservoirs of this type (Prospect) the shore is well covered with low-growing sedges and rushes and the bottom often covered with *Nitella* and *Potamogeton*. The younger reservoirs show very little growth along the shore line, but the bottom is usually well covered with *Riella* and *Chara*. This type includes Mesa Nos. 1, 2 and 3, Prospect, Broadmoor, and Colorado Springs (Mesa). The most favorable conditions for plant and animal growth are found in reservoirs of the third type. During heavy rains great quantities of silt and organic matter are carried into the supplying ditches and often directly into the reservoirs. The water is stored throughout the season, or very nearly, and reaches a temperature as high as 25°. The shore line is overgrown as a rule with rushes, sedges, willows, etc., and the reservoir filled with growths of *Potamogeton, Philotria, Batrachium,* and *Chara*.

The plains lakes differ from the alpine lakes in having a higher temperature, and also in the fact that this high temperature continues for a longer period. Like the alpine lakes they are subjected to low relative humidity of the air and consequently rapid evaporation.

Plant Growth

Aside from the microscopic algae, perhaps the most abundant plant to be found in the plains lakes is *Chara foetida*. The flora of the reservoirs of the third type is largely *Potamogeton lucens*, together with a lesser amount of *Batrachium flaccidum*, and *Philotria angustifolia*. These plants, together with *Cladophora, Spirogyra,* and *Zygnema* often form a dense growth on the surface of the pond. This is especially true at Boulder and Jenks. Reservoirs of the second type seldom show plant growth at the surface, but an examination of the bottom usually reveals a luxuriant growth of *Chara foetida, Potamogeton perfoliatus, Myriophyllum spicatum, Nitella,* and *Riella*. In reservoirs of the first type no macroscopic plants were found.

Turning now to the alpine lakes, we find in the smaller bodies, or ponds, an abundant growth. According to Clements (1904: 353) the most important plants in these alpine lakes are, in order of their importance, *Sparganium angustifolium* and *Potamogeton alpinus,* and those of secondary importance, *Utricularia vulgaris, Callitriche bifida,* and *Isoetcs lacustris paupercula.* In Isoetes Lake there is in addition to those cited above a rather rank growth of *Batrachium flaccidum* near the center of the lake, inside of a broad zone of *Sparganium.* Michigan Lake is completely overgrown with *Sparganium angustifolium,* and also shows a rather abundant growth of moss. At Bald Mountain Lake the mosses constitute the only macroscopic flora. The other types of alpine lakes show no flora aside from the algae.

Vertebrate Fauna

The vertebrate fauna is never abundant. *Rana pipiens* is present in small numbers in the reservoirs of the third class. *Amblystoma* and *Bufo* larvae, although present, are never abundant. Here are also found a few fish, chiefly suckers. In reservoirs of the second class only a few larval salamanders and suckers have been noted. Exceptions should be made in the case of Prospect Lake, in which tadpoles are at times very abundant and which has also been stocked with trout. Reservoirs of the first type have no vertebrate fauna.

The most abundant vertebrate form of the alpine lakes is the larva of *Amblystoma.* These were especially abundant in Mirror and Ribbon lakes and are occasionally found in Isoetes and Michigan lakes. The writer has observed a few large trout in Mirror, Ribbon, and Isoetes lakes. In the latter they are probably not found at the present time because of the changes in the character of the water. These lakes are all connected with Beaver Creek, from which mountain trout are still occasionally taken. In none of these lakes has the writer ever seen minnows. Lake Moraine, on the other hand, is fairly well stocked with trout and suckers, and here are observed great numbers of minnows. Dead Lake has no vertebrate fauna (Shantz 1905: 258).

The Plankton

It is evident that in such small bodies of water no sharp line can be drawn between the plankton, the bottom, or the littoral fauna and flora. Even in the largest lakes a better classification would be into plankton and littoral, since the bottom is never more than a

few meters from the surface, and littoral forms are always abundant here.

Collections were taken with a Birge net, from both surface and the bottom, and in only a few cases are the plankton forms absent in the bottom hauls.

The alpine lakes,—Mirror, Ribbon, Dead, and Moraine,—and the lowland lakes of the first and second types,—Mesa Nos. 1, 2 and 3, Colorado Springs Nos. 1 and 2, Prospect, and to a lesser extent Portland,—showed a plankton comparatively free from insect larvae and other forms characteristic of bottom and shore.

There is great variation in the amount and kind of plankton found in the different lakes. In none of the lakes studied does a "bloom" appear. Even in the smaller ponds there is never an abundant development of Cyanophyceae. Except for a very short time at the end of summer the plants are never a prominent part of the plankton.

Plankton of the Alpine Lakes

Dead Lake.—The plankton of this lake is far more abundant than that of any other alpine lake studied. Collections taken on May 20, 1904, show a plankton almost entirely of larvae of *Diaptomus shoshone* and *Branchinecta coloradensis*. On June 5 *Daphnia* was present in small numbers and this form had increased greatly by June 17. *Diaptomus* and *Branchinecta* were full grown on July 12. These species are large, noticeable forms, visible to the naked eye. The former is of a very deep red color. At this time there was also an increase in plant growth. Cyanophyceae and diatoms were present and *Characium* was more or less abundant upon the appendages of the crustacea. By July 29 the algae were more noticeable and on August 12 they were a rather important part of the plankton. By this time *Branchinecta* had entirely disappeared and *Diaptomus* and *Daphnia* were present in about equal numbers. On August 13, 1903, and August 15, 1905, the plankton consisted almost entirely of *Diaptomus*. The next collections were made on August 26, but this time there were about three *Diaptomus* to one *Daphnia*. A few specimens of *Chydorus* were also taken. On September 17 *Spirogyra* and *Oedogonium* were present in large numbers and these, together with other algae, constituted the greater part of the plankton. *Diaptomus* still continued to be more numerous than the Cladocera. The latest collections were made on Octo-

ber 4. This collection consisted largely of the algae, *Spirogyra, Oedogonium,* and diatoms. *Diaptomus* still remained the most important element of the fauna, *Daphnia* had decreased, while *Chydorus* was found in considerable numbers.

Throughout the summer months *Diaptomus shoshone* is abundant at all times in the plankton of this lake. In all probability it continued for a considerable period after the last collection. Material collected at this lake on September 17, 1904, was taken in a small vial to Lincoln, Nebraska, placed in an icebox with a temperature ranging from 11° to 13°, and kept in a living condition for some time. In this vial there were two specimens of *Diaptomus shoshone,* which remained alive and active until April 5, 1905, having lived for six and one-half months in a three-drachm vial. About two weeks later two larvae with the characteristic red color were noticed, but these soon died. No winter collections were taken from this lake, but it seems likely from the above experiment that this form would be taken during the winter months.

In general, we may say that *Diaptomus* and *Daphnia* continue throughout the season, that *Branchinecta* is present during the spring and early summer, and that the algae become the most important constituent during the autumn.

Mirror and Ribbon Lakes.—A very meager plankton was found in these lakes. Conditions for life were almost identical in the two. Three good hauls with the net seldom gave more than enough to cover the bottom of the vial. They were separated by a narrow bar, about 50 m. in breadth, through which they were connected by a stream from Mirror to Ribbon.

In amount the plankton does not vary to any very great extent from month to month. Ribbon Lake showed on May 20, 1904, a few larval copepods, a few *Daphnia,* and also a few *Anuraea cochlearis* and diatoms. On June 5 practically the whole collection was of *Diaptomus,* with a very few *Anuraea cochlearis* and *Anuraea* sp. On June 17 the only change noted was the appearance of a few *Cyclops* and diatoms. *Anuraea cochlearis* was most important in the plankton on July 12. *Diaptomus* was also present, as well as *Anuraea* sp., but on July 29 *Diaptomus* was again more abundant and on August 12 practically the whole collection was of *Diaptomus.* An increase in the number of *Diaptomus* was noted August 26. At this date there were also a small number of *Daphnia* and *Cyclops.*

On September 17 the forms found were, in order of their importance, *Diaptomus, Daphnia, Anuraea* sp., diatoms, and *Zygnema. Anuraea* sp. was the most important form on October 4, and *A. cochlearis* and *Diaptomus* were present in small numbers. In Mirror Lake no *Daphnia* were taken. This agrees with the report by Birge (1904: 149) on Ward's collections. In these lakes the chief element of the plankton is *Diaptomus.* During June, July, and August *Anuraea* was found, and in the latter part of the summer algae,—*Spirogyra, Zygnema,* and diatoms,—had increased and constituted a considerable part of the plankton.

Lake Moraine.—This lake shows much less plankton than any of the others. The vials showed no visible forms and almost no organic fragments. A meager plankton was taken on May 20, 1904, consisting entirely of Rotifera, *Asplanchna* and *Anuraea* being the most abundant. By June 5 *Anuraea cochlearis* constituted practically the whole plankton, with the exception of an occasional diatom, *Asplanchna,* and one or two other rotifers. An increase in the number of *Asplanchna* was noted on June 17, while on July 12 there was a marked increase in the amount of plankton, the dominant species being *Anuraea cochlearis tecta.* The plankton on August 26 was by no means as abundant, there being only an occasional *Anuraea cochlearis, Pediastrum,* or diatom. The last collections made showed very little life of any kind, only an occasional diatom or rotifer.

The most noticeable feature of the plankton of this lake is the entire absence of crustacea. Very few Cladocera were taken in the bottom hauls, but at no time were they present in the plankton. A possible explanation of this may be found in the presence in this lake of great numbers of minnows. This lake is also different from the others under consideration in that the plankton is almost exclusively of Rotifera and that even in autumn there is no appreciable amount of algae developed.

The plankton of the alpine lakes is never abundant. For the greater part of the year animals are the chief constituents. Only late in the fall do the algae become dominant. Dead Lake shows the richest plankton, and Lake Moraine the least amount, while Mirror and Ribbon were intermediate as to the amount of plankton produced. In Mirror and Ribbon the plankton was largely *Diaptomus,* in Dead *Branchinecta* and *Daphnia* also become important

parts, while in Moraine the plankton is almost entirely of Rotifera. The maximum amount of plant growth is not at the time of highest temperature, but occurs much later.

Plankton of the Plains Lakes

Portland.—This is the only reservoir of the third type which can be said to have a plankton distinct, to some degree at least, from the plant and animal life of bottom or shore. The collections on July 14 showed great numbers of *Daphnia.* There were also present *Anuraea cochlearis, Anuraea* sp., *Cyclops,* and a few threads of *Spirogyra.* The plankton at this time was more abundant than in any other collection taken from this lake. By the nineteenth of August *Diaptomus* was the principal form, together with *Daphnia, Anuraea, Difflugia, Pediastrum, Dictyosphaerium,* and *Volvox.* The plankton of this collection was about one-fourth the amount of that taken July 14, while on October 2 not more than one-eighth the original amount was present, made up largely of *Daphnia, Diaptomus,* and diatoms. (The collection on September 2, 1903, showed an exceedingly rich plankton, in which the following elements were of about equal importance: *Daphnia, Diaptomus,* and *Volvox,* with a lesser amount of *Pediastrum.*)

Mesa Reservoir No. 3.—Although very young this reservoir shows a comparatively abundant plankton. Collections made May 19, 1904, were largely of *Daphnia,* with a very few *Cyclops.* Nine-tenths of the plankton on June 8 was *Daphnia,* but *Diaptomus,* diatoms, and desmids also occurred in considerable numbers. The most abundant plankton was collected June 22, when there were present, in addition to those already cited, many larval copepods, and also *Chydorus* and *Cosmarium.* The next collection was only about one-third as large and was taken on July 21. *Daphnia* had almost entirely disappeared; *Diaptomus* characterized the plankton, but *Volvox* and *Conochilus* were also numerous, while diatoms and *Cosmarium* were present in considerable numbers. The plankton on August 20 was made up almost entirely of *Diaptomus* and *Conochilus, Volvox* having disappeared. The next collection, on September 15, showed a decrease in the animal and an increase in the plant constituents of the plankton. The forms found were, in the order of their importance, diatoms, *Oedogonium, Diaptomus, Chydorus,* another cladoceran, *Cosmarium,* and *Difflugia.* The latest

collections were on October 4, and showed *Diaptomus, Conochilus, Daphnia,* diatoms, and filamentous algae.

It will be seen from the above that *Daphnia* dominates in the spring plankton, *Diaptomus* in the summer, and *Conochilus* and algae late in the summer and autumn. At the very end of the season there was again an increase in crustacea.

Mesa No. 1.—The earliest collections from this reservoir were on May 19, 1904. At this time there was almost as much plankton as at any period during the year. *Chydorus, Daphnia, Diaptomus,* and copepod larvae were present in about equal amounts. There was a considerable amount of *Mesocarpus. Daphnia* and *Diaptomus* were about equal on June 22, at which time *Chydorus* and several ostracods were taken. The plankton was more abundant on July 21 than at any other time, and was made up of the same constituents as noted above. On August 20 Cladocera had entirely disappeared, the bulk of the plankton being of *Diaptomus* and of *Conochilus.* A marked decrease in the amount was noted on September 15. *Diaptomus,* diatoms, and two *Daphnia* were found, while on October 4 the plankton was made up of a very small number of diatoms.

Collections made during 1903 and 1905 do not show any marked variation from those of 1904. Mesa No. 2, in a general way, shows very little variation from that of No. 1.

Prospect Lake.—This lake has never yielded as much plankton as Mesa Nos. 1, 2 or 3, or Portland. On May 27, 1904, *Cyclops,* diatoms, rotifers, and *Chydorus* constituted the very meager plankton. *Bosmina* was by far the most important element of the plankton taken June 24 and July 14. *Cyclops,* diatoms, Cyanophyceae, and *Anuraea cochlearis,* and several rotifers were present. The most abundant plankton ever taken from this lake was collected August 6, 1904. It was almost entirely of *Bosmina* with a few *Cyclops, Anuraea, Rattulus,* and *Peridinium.* The character of the plankton had greatly changed on October 2. The forms, in order of their importance, were *Peridinium, Bosmina,* copepod larvae, diatoms, *Pediastrum, Merismopedia, Staurastrum, Cosmarium, Oscillatoria,* and *Cyclops.* Although the last collection was made up of a number of elements the total amount was very small.

The plankton of this lake contrasts sharply with that of the other lakes in the fact that here for the first time *Bosmina* is found. All of the lakes considered up to this point, with the single excep-

tion of Lake Moraine, show a plankton dominated by *Diaptomus*. In this lake, however, *Diaptomus* is almost entirely lacking. *Cyclops* is present but, with the exception of the last collection and that taken May 27, *Bosmina* was at all times the most important element. The presence of *Peridinium* and its dominance in the October collection is also a notable feature.

Colorado Springs Reservoir No. 2.—Before considering the plankton of this reservoir it will be well to mention one or two facts with respect to the water supply. The water which supplies this reservoir passes first through the pipes of the Colorado Springs water system. These go direct to the consumer, and it is only the excess of water which passes into this reservoir or reservoir No. 1. While these reservoirs are continually being supplied with water from the pipes, they are also being drawn upon by the consumer. In consequence, the water may remain in the reservoir for only a few hours. This fact alone is probably sufficient to explain the very meager plankton found here. Many collections show absolutely no living forms, but occasionally an organism will be taken. About the only plankton taken from reservoir No. 2 was on June 8, when a very few rotifers were present, as well as one larval copepod. On June 22 no organism was found, but on October 2 a few specimens of *Peridinium* were noted in the collection.

Reservoir No. 1.—The collection on June 8, 1904, in this reservoir, as well as that on June 22, showed no organisms. The most abundant plankton was found on October 2. Here the collection showed an occasional *Peridinium, Merismopedia,* or rotifer. The bottom collection on this date showed a rather large number of *Merismopedia,* with a few diatoms, rotifers, and insect larvae.

It will be remembered that the water supplying these two reservoirs comes originally from the intake in Bear Creek and Ruxton. The water supply at Bear Creek is from a mountain stream, in which plankton forms would not be found. That supplied from the intake on Ruxton has come from Lake Moraine, a distance of about three miles in an open stream. It will also be remembered that Lake Moraine showed almost no plankton aside from the Rotifera. Under these conditions one would not expect plankton to develop in reservoirs Nos. 1 and 2.

Littoral Flora and Fauna

Here it seems best to include the animal and plant forms which occur in such numbers in the mountain ponds and the plains reservoirs of the third type.

Bald Mountain Lake.—Of the mountain ponds perhaps the most interesting, because of its great altitude, is that found on Bald Mountain. Collections from this pond made June 17, 1904, at which time ice still covered the pond, were largely of *Cyclops, Chydorus,* and nematodes. There were also many diatoms and insect larvae as well as occasional rotifers. *Dinobryon* and *Macrobiotus macronyx* were also noted. July 12 showed *Dinobryon,* diatoms, *Zygnema, Mesocarpus,* as well as copepod larvae. There were also noted *Macrothrix montana* and *Chydorus.* On August 12 *Mesocarpus* and *Zygnema,* together with a number of the Cyanophyceae, constituted the principal part of the flora, while the fauna was almost entirely of *Chydorus, Cyclops,* and Rotifera. Life was not as abundant on August 26, when larvae, diatoms, *Gomphiosphaerium,* and *Cyclops* were the principal forms. The September 17 collection showed an abundance of algae, chiefly *Mesocarpus* and *Zygnema,* filamentous and other diatoms, and *Gomphiosphaerium.* Isopods, rotifers and copepod larvae were also taken. Collections on August 15, 1905, showed a number of Ostracoda in addition to those already mentioned.

Michigan Lake.—Of the alpine lakes Michigan shows the greatest abundance of living forms. The earliest collections, made on May 20, show chiefly rotifers. *Dinobryon* was the most important form on June 17, while on July 12 a very few *Cyclops* and *Diaptomus* were taken. On this date *Dinobryon* had disappeared. On July 29 *Daphnia* was the most abundant form, *Anuraea cochlearis* was next in importance, and *Cyclops* was also found. A very few specimens of *Bosmina* were taken in this lake. The collection on August 12 was much richer than any of those previously taken. *Diaptomus, Daphnia,* and *Anuraea cochlearis* were the most abundant. About the same forms were found on August 26, but there was considerable increase in the amount of copepod life. Algae were dominant on September 17, chiefly *Spirogyra,* and a lesser amount of *Zygnema* and diatoms. Of animal forms, *Daphnia* and *Diaptomus* were of the greatest importance. The latest collections were made on October 4. These were almost entirely of *Spirogyra,* with a considerable number of *Daphnia* and *Diaptomus.* Insect larvae were abundant in all of the collections.

Isoetes Lake.—In this lake the collections on May 20, June 5 and 17, July 12 and 29, showed only an occasional rotifer, *Diaptomus, Dinobryon,* diatom, or insect larva. The collections were largely of silt and organic remains. On August 12, however, *Chydorus* was rather abundant, as were also Rotifera, *Dinobryon,* diatoms, and insect larvae. The collection on August 26 was largely *Diaptomus, Chydorus, Cyclops,* and *Anuraea.* On September 17, and again on October 4, a small amount of *Spirogyra* and *Zygnema* made up the greater part of the haul.

Although the conditions in these alpine ponds seem especially favorable for growth, it will be seen from the above that in them life is not abundant during the early part of the summer period. During the latter part of the summer and continuing until the approach of winter the algae are developed in considerable numbers, in some cases filling up the pond almost completely.

Boulder Lake.—Of the lowland lakes of the third type, Boulder is perhaps the best example. A collection made here on May 27, 1904, showed only a few larval copepods. On June 23, however, Cladocera were abundant, chiefly *Bosmina.* *Cyclops* also was rather abundant at this time. Collections on June 14 were especially rich in *Diaptomus, Daphnia,* other Cladocera, *Cyclops, Ostracoda, Spirogyra, Oedogonium,* and insect larvae. The same might be said to be true of the collection on August 6, except that the insect larvae, *Diaptomus,* and Ostracoda were more abundant. The richest collections were taken on September 16, when the surface showed chiefly *Daphnia, Diaptomus, Cyclops, Anuraea,* and many algae. The collections on October 2 did not differ markedly from those of September 15. This pond also showed *Volvox, Coleochaete, Bulbochaete,* and *Cladophora.*

In reservoirs of the second type the abundant growth of *Chara* and other macroscopic plants insures an abundance of insect larvae, Cladocera, diatoms, and desmids. Without exception all of the plankton forms were also taken from the bottom. Colorado Springs reservoirs Nos. 1 and 2 showed a very little growth of any kind from bottom hauls. *Merismopedia,* an occasional diatom, rotifer, or insect larva were the elements of the bottom hauls.

Of the alpine lakes, exclusive of the ponds, Dead Lake showed the most abundant life at the bottom. In addition to the plankton forms already mentioned insect larvae and Turbellaria were most

abundant. From this bottom one small bivalve mollusk was taken, this being the only bivalve mollusk found by the writer in any of the lakes under consideration.

Bottom hauls from Mirror and Ribbon lakes did not differ essentially from the plankton hauls except in the greater abundance of diatoms.

Reservoir No. 5

This reservoir covers the old sites of Mirror, Ribbon and Marsh lakes, as well as a considerable amount of mountain meadow and thicket region lying near them. It was completed in 1904, but it was not until the middle of the summer of 1905 that this reservoir was filled. All shrubs lying within the basin were cut down and the roots and plant remains removed in so far as possible. In many places all surface vegetation was removed, leaving a clean gravel bottom. Near the upper end of the reservoir and also along many of the sides, the water has spread out over the thick mat of mountain meadow. This meadow is a dense growth of grasses and herbs, which never rise more than a few centimeters above the surface of the soil and form a thick mat-like layer. The old bottoms at Mirror and Ribbon lakes have been left undisturbed. Marsh Lake, on the other hand, was completely drained and the bottom scraped out and lowered several meters.

We may distinguish three types of bottom in this reservoir: First, the original clay bottoms of Mirror and Ribbon lakes; second, the clean soil or gravel bottom; and, third, the submerged mountain meadow.

On July 14, 1906, water was turned into this large reservoir and by August 21 the lakes had been completely covered. On this date the water level over the former Mirror Lake was about 5 m. above that of the old lake surface. According to the report of the man in charge of this reservoir the water was rising at this time at the rate of about 3.8 cm. each day. At the edge of the reservoir and extending in to the depth of a meter or more could be seen many flowering plants and fungi, which had not yet decayed as the result of having been covered with water.

The water supply of this reservoir comes from the stream leading from Windy Point on Pike's Peak and is consequently free from plankton forms. In the old basins of Mirror and Ribbon lakes there still remained a large amount of water, but this, by the addition of

water from the mountain streams, was diluted many times. This would naturally result in a great decrease in the amount of plankton in proportion to the amount of surface.

Collections were made in this reservoir on August 21 and September 24, at which time the temperature was 15° C. No very noticeable difference was found in the plankton of these two dates, with the exception that the algae were somewhat more abundant on the latter date. At this time plankton taken over the old bed of Ribbon Lake showed *Daphnia, Diaptomus, Anuraea cochlearis,* and several other rotifers. Unicellular algae were also rather abundant in this collection. At the same time a collection over the Mirror Lake basin showed *Daphnia, Diaptomus, Chydorus, Mesocarpus, Zygnema, Anuraea cochlearis,* and *Dinocharis.* This plankton was much more abundant than that taken over the former Ribbon Lake. Several reasons may be given for the abundance of the plankton over the old Mirror Lake basin. The wind usually blows from the former to the latter and this would carry with it the greater part of the plankton. Around the old bed of Mirror Lake there is submerged a large area of mountain meadow; this would mean a rich supply of food for both plant and animal life in the region adjacent to it.

At the lower end of the reservoir, at the place where Marsh Lake was formerly located, *Anuraea cochlearis* and an occasional *Diaptomus* or *Cyclops* constituted the entire plankton. Plankton taken on the new gravel bottom was even less abundant than that taken from over the former Marsh Lake, although made up of the same elements. The conditions over the latter area differ very little from those over the new bottom, because of the fact that the old bed of this lake was entirely removed.

The most abundant plankton was taken over submerged mountain meadow. Here there was an abundance of *Mesocarpus* and *Zygnema, Diaptomus,* desmids, and rotifers. In addition to these forms there was also present a great amount of plant fragments, chiefly anthers, pollen, etc.

The life at the bottom of the old lake beds had changed very little. The two principal changes in habitat, increase in food and increase in depth, had operated for only a short time and the changes were only a very slight increase in the amount of life, chiefly algae. On the gravel bottoms living forms were hardly to be found, but

on the old submerged meadow life was very abundant. The chief growth was of the algae, *Zygnema* and *Mesocarpus*. The animal life was almost entirely *Diaptomus, Daphnia, Chydorus, Anuraea,* and other rotifers.

By comparing the collections taken from these lakes in 1904 and 1905 with those taken from the reservoir in 1906 a great increase is noticed in the amount of plankton. There has also been an increase in the number of species and genera represented. This result would naturally be expected when we consider the conditions of the two regions. The old lake beds of Mirror and Ribbon lakes had particularly clean bottoms and shore lines. There was no noticeable plant growth and the microscope revealed only a few diatoms and occasional filaments of algae. The reservoir, on the other hand, has a bottom largely made up of abundant plant and animal remains and these form a most abundant food supply for both plants and animals.

Comparison of Plains Lakes and Alpine Lakes

In comparing the life of the plains lakes with that of the mountain lakes, the most striking thing is the greater abundance of life in the plains lakes. The plankton collections from these lakes contain many times the amount of material shown in collections from the alpine lakes. Exception should be made in the case of Prospect Lake, which at no time gave more plankton than did Dead Lake. This is also true of Colorado Springs reservoirs Nos. 1 and 2, but this condition is explained by the peculiar conditions of water supply.

In a very general way the plankton of Lake Moraine resembles that of the two reservoirs just mentioned. It is very meager in each case and is largely of Rotifera. The alpine lakes, Mirror, Ribbon, and Dead, were or are dominated by *Diaptomus* and *Daphnia,* and are to some extent comparable to Mesa reservoirs Nos. 1, 2 and 3, and to Portland Lake, which are dominated by species of the same genera. Prospect and Boulder lakes are alike in having the plankton largely of *Bosmina.* Portland Lake, a very young reservoir, will in a few years approach more closely to Boulder Lake, and Mesa reservoirs Nos. 1, 2 and 3 will in time become like Prospect Lake.

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EXPLANATION OF PLATES

Plate V

A map of the Pike's Peak Region showing the relative position of the principal lakes and reservoirs. The lakes and reservoirs are relatively large in comparison with the other features shown.

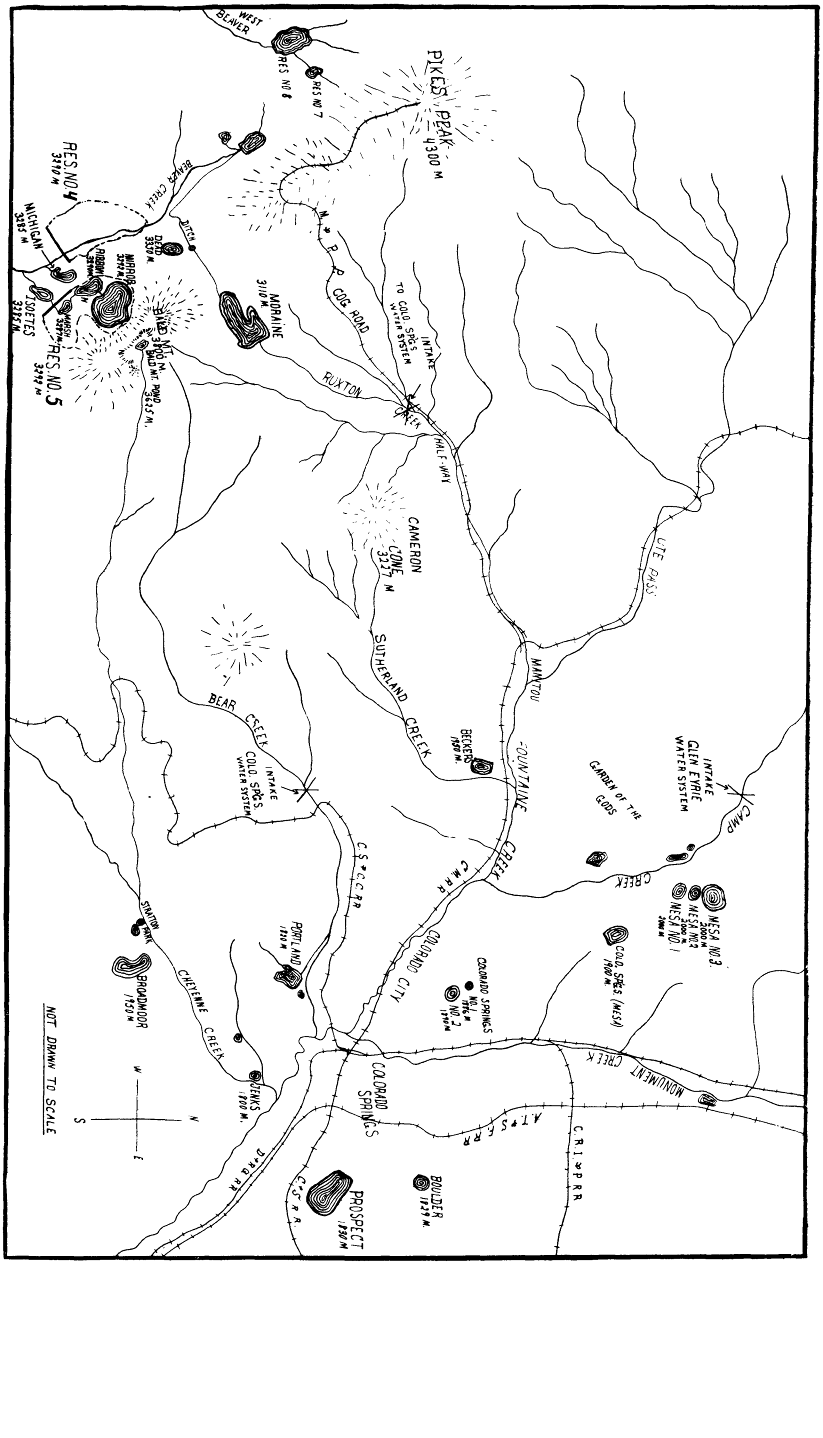
Plate VI

Seven Lakes as seen formerly from Bald Mountain. 1, Lake of the Rocks; 2, Ramona Lake; 3, Michigan Lake; 4, Isoetes Lake; 5, Marsh Lake; 6, Ribbon Lake; 7, Mirror Lake. (Taken by permission from Ward, 1904, Pl. XXVI; photographed by Professor F. E. Clements in 1899.)

Plate VII

A view of Reservoir No. 5 from Bald Mountain. The region shown is the same as that shown in Plate VI and the members are the same as for that plate. Marsh Lake, Ribbon Lake and Mirror Lake form one reservoir, while a second one (Reservoir No. 4) has been formed, marked 8 in the plate. (Photograph by Professor F. E. Clements, Aug. 28, 1906.)

PLATE V



PIKES PEAK
4300 M
RES NO 7
RES NO 8
WEST BEAVER
RES.NO 4
3390 M
BEAR CREEK
MICHIGAN
3285 M
DITCH
DEAD
3330 M
MIRROR
RIBBON
ISOETES
3275 M
MARSH
RES.NO.5
3292 M
BALD MT.
3700 M.
BALD MT. POND
3625 M.
MORAINE
3110 M.
M. & P. P. COG ROAD
INTAKE
TO COLO. SPGS. WATER SYSTEM
RUXTON
CREEK
HALF-WAY
CAMERON
CONE
3227 M
UTE PASS
SUTHERLAND
CREEK
MANITOU
BEAR
CREEK
INTAKE
COLO. SPGS.
WATER SYSTEM
BECKERS
1920 M
FOUNTAINE
CREEK
GARDEN OF THE GODS
INTAKE
GLEN EYRIE
WATER SYSTEM
CAMP
CREEK
C.S. & C.C. RR
C.M. R.R.
STRATTON PARK
BROADMOOR
1950 M
CHEYENNE CREEK
PORTLAND
COLORADO
CITY
MESA NO.3
MESA NO.2
MESA NO.1
COLO. SPGS. (MESA)
1900 M.
COLORADO SPRINGS
NO.1
NO.2
JENKS
1900 M.
COLORADO
SPRINGS
MONUMENT CREEK
A.T. & S.F. R.R.
C.R.I. & P. RR
D. & R.G. R.R.
C. & S. R.R.
PROSPECT
1830 M
BOULDER
1829 M
NOT DRAWN TO SCALE
W
S
N
E

PLATE VI

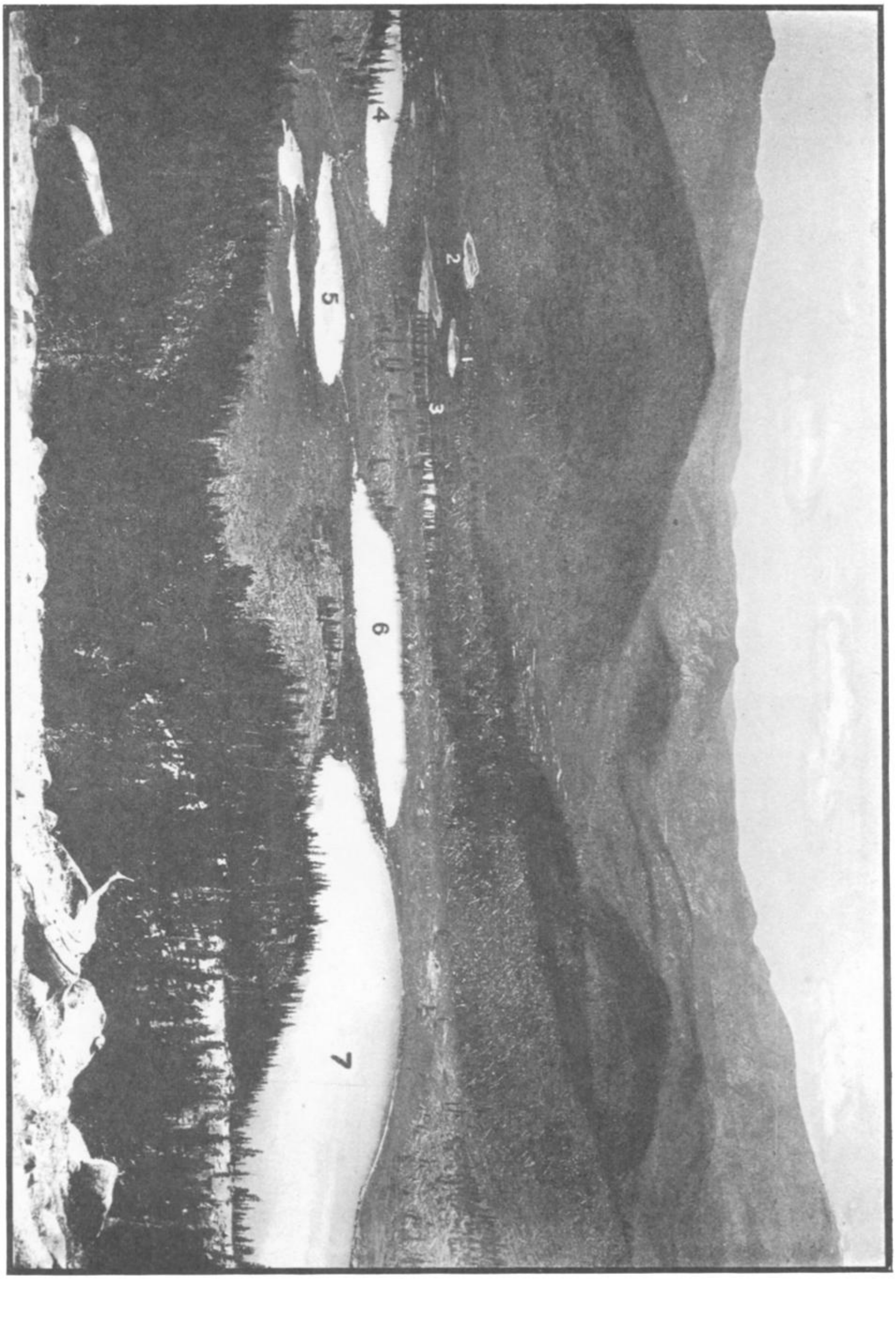


PLATE VII